

# OPTICAL INTERFEROMETRY FROM THE LUNAR SURFACE

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## ABSTRACT

A preliminary study was conducted to determine the feasibility of a concept for a robust and expandable lunar optical interferometer that would perform new science even with the modest first element. With a phased approach, early steps verify technology for later phases. As elements are added to the observational system, astronomical observations unachievable from the surface of Earth are made possible. The initial experiment is supported by the Lunar Ultraviolet Telescope Experiment (LUTE), a 1-meter-class transit telescope. The first interferometry element, the Lunar Interferometer "technology Experiment (LITE), will perform ultraviolet astrometry and will demonstrate critical interferometer technologies (including optical delay lines and nanometer-level metrology) in the lunar environment. Subsequent elements will add capability, building on the design and performance of both LITE and LUTE. The starlight collectors will be based on the LUTE design but will be capable of being pointed. They will relay the received light to a centrally positioned beam combiner. As more collectors are added, the system will build up from an astrometric interferometer to an imaging interferometer with 100-m-class baselines. Because discrete elements are used, if any one of the collectors fails completely, the system remains functional.

## INTRODUCTION

This study was undertaken for the NASA Advanced Programs Branch of the Astrophysics Division of The Office of Space Science. JPL was asked to undertake a study of the use of the Lunar Ultraviolet Telescope Experiment (LUTE), developed by Marshall Space Flight Center as the starting point for a lunar interferometer. This brief paper outlines the results of the work performed by Marshall and JPL.

LUTE is a 1-meter-class ultraviolet transit telescope that would be landed robotically on the moon. After an initial alignment, it would remain fixed, observing whatever portion of the sky moved into its field of view. Although this greatly limits the number of targets that can be observed, it significantly reduces the cost/complexity of the flight and ground systems. The proposed implementation begins with a companion experiment on the first LUTE, without any modifications to LUTE itself. It ultimately builds to a fully functional imaging interferometer with 100-m-class baselines.

## EVOLUTIONARY LUNAR OPTICAL INTERFEROMETER

We evaluate a concept for a robust and **evolutionary** lunar optical **interferometer** which is capable of new science even with the first element. In this phased approach early steps include technology verification and demonstration for later phases. With the addition of each element to the system astronomical observations unachievable from the **surface** of Earth are enabled. It begins with an experiment **landed** with and supported by the Lunar Ultraviolet Telescope Experiment (LUTE), a 1-meter-class transit telescope. The augmented LUTE is called the Lunar Interferometer Technology Experiment (LITE) and will perform ultraviolet **astrometry** and will demonstrate critical interferometer technologies (including optical delay lines and nanometer-level metrology) in the lunar environment.

Subsequent elements will build upon the design and performance of both LITE and LUTE. The starlight collectors will be based on the LUTE design but will be capable of being **pointed**. They will **relay** the received light to a centrally positioned beam combiner. As more collectors are added, the system will build up from an **astrometric** interferometer to an imaging interferometer with 100-m-class baselines. Because discrete elements are used, if any one of the collectors fails completely, the system remains functional. We expect that evolving from the basic LUTE design and using many separate identical interferometer elements and an incremental deployment will help minimize the cost.

A capability to position the elements of **LITE** on the lunar surface to within about 5 m of the desired **position** is a **requirement**, and was not addressed in the study. Another **assumption** is that the **optomechanical** hardware from the Stellar Interferometer Tracking Experiment (SITE), a proposed technology experiment, would be **re flown**, with little or no modification. The electronics would need some redesign because on SITE they are **in** the benign environment of the shuttle orbiter's crew compartment. **Nevertheless**, a significant savings is possible by reusing much of this hardware and taking advantage of whatever we **learn** on the SITE flight. SITE (and, therefore, LITE) will incorporate nanometer metrology, not the **picometer** metrology ultimately required for the big lunar interferometers. LITE will work in the ultraviolet, thus seeing targets unavailable from the **surface** of Earth. LITE would be packaged on the lander with LUTE and be deployed after landing as depicted in Figure 1. Note that SITE is intended to take advantage of the shuttle orbiter's ability to rotate, thus changing the instrument orientation. That will not be straightforward in LITE, but even without moving it can make measurements of such things as some orbital elements of binary stars.

Phase 1 is the **first** collector, which is the deployment of C1 only (Figure 2). Phase 2, the first full scale **interferometer** includes the Phase 1 collector, C1 plus C2 and the first beam combiner (BC1). C1 (and subsequent collectors C2 through C6) differs from LUTE in several ways. It needs to be articulated (LUTE does include a mechanism for pointing itself, but it is used for initialization and infrequent adjustments.) But this actually will allow this first element, C1, to follow up on LUTE's work by performing targeted observations. It also needs the kind of multi-star feed incorporated in SONATA, a proposed optical interferometry free flying mission, and the Mt. Palomar interferometer. In this system, the field of view of the telescope is split into quadrants, and the corresponding quadrants from different telescopes are combined to create interference. Of course, the collectors will also have to be

able to direct the starlight to the beam combiner ("BC1"). Because of the number of reflections that **will** be involved, this whole **second** stage might be more appropriate for **visible** wavelengths, as **uv** **will** suffer significant losses. A minor modification is that each element will need a retractable dust **cover** or some other system to protect it during the **introduction** of subsequent elements. And with the assumption of about 5 m optical path **delay** on the beam combining station, the elements will need to be positioned to that level.

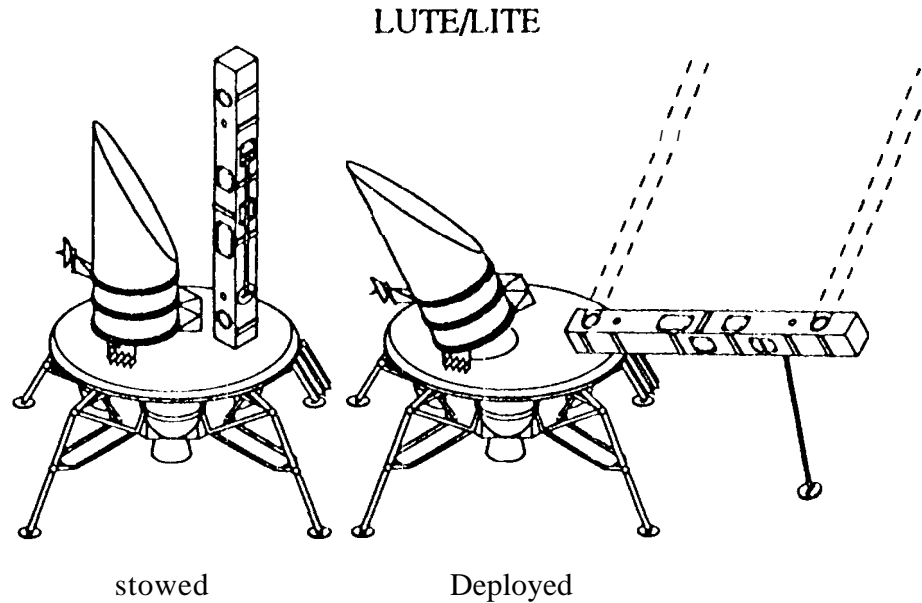


Figure 1. Lite Deployment Concept

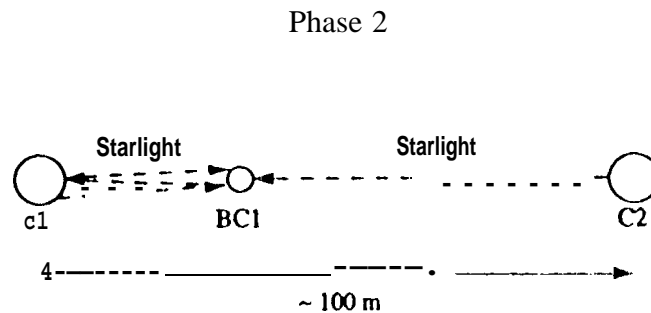


Figure 2. Optional second round trip of starlight from C1 to BC1 allows a discrete change in **pathlength** (equivalent to a long, **fixed** delay line), thus enabling the interferometer to view 2 widely **separated** fields in the sky.

Perhaps c2 and BC1 could be landed together, with one of them roving from the landing **platform** to its required location. In this case, a functional **interferometer** (Phase 2) could be **achieved** more quickly. Because of the short optical delay available on BC1, nominally only one patch of the sky would be observable. But we include an extra set of mirrors to allow the option of having starlight go directly from C1 to be combined in BC1 or to go from C1 to BC1 then back to C1 then back to BC1 again for combining with light from C2. In this way, with C2 twice as far from BC1 as C1, the ratio of optical path distance

(for the starlight) from C1 to BC1 to the optical path distance from C2 to BC1 can be made 1:2 and 3:2. This allows two separated pieces of the sky to be viewed without increasing the delay line travel. With the proper orientation of the baseline connecting C1 and C2, this enables 2-axis astrometry to be accomplished with this linear system by observing targets twice as the Moon's rotation carries them through the two observable regions of the sky.

Phase 3 adds a third collector (C3) (Figure 3) and a new beam combiner (BC2) that, again, perhaps could be landed together. BC2 needs to be positioned, as shown at the center of the equilateral triangle defined by the three collectors, again because of the relatively short delay available. It will be designed to accept inputs from at least six collectors. Because there are better projections of the new baselines onto the two axes of celestial targets' locations, this phase can do better astrometry. In addition, this system now can do imaging,.

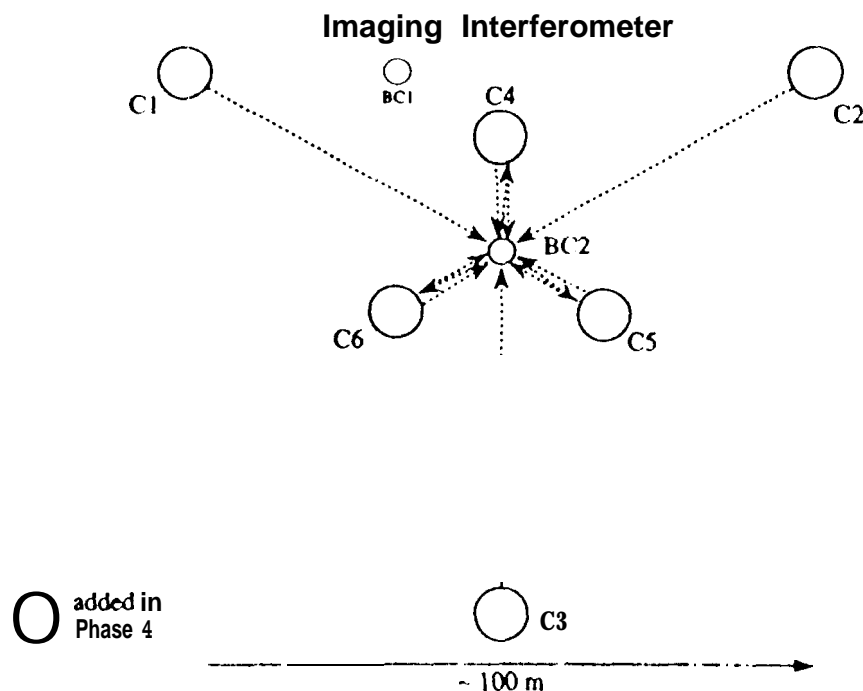


Figure 3. Phase 4 concept for adding imaging capability.

To improve the  $(u,v)$  plane coverage, phase 4 adds three more collectors. As indicated, they also are arranged in an equilateral triangle around BC2, but by using the triple bounce trick, they can be stationed closer to the center. Thus we get a new set of baseline lengths and orientations, which is exactly what is needed for imaging more complex targets. Note that if any one of the collectors fails completely, we still have a functional system.

#### ACKNOWLEDGMENTS

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